## THE FRANCO-SCANDINAVIAN STATION FOR AERIAL SOUNDINGS.

By LEON TEISSERENC DE BORT, dated Viborg, April, 1903.

Since it has been proved by the exploration of the meteorological phenomena of the free air, by means of balloons and kites, that the sudden and accidental variations that we are able to observe at the surface of the ground also occur at considerable heights, the utility of continuous explorations and, indeed, the necessity for such investigations have been recognized, if we wish to obtain an accurate conception of the great atmospheric disturbances. Until very recently we have had very little data of this kind, since the use of sounding balloons necessarily excludes continuity and the scientists who have sent up kites have always been careful to avoid unfavorable conditions, as this latter method is too delicate and costly to risk apparatus when the conditions render a catastrophe probable. However, the results obtained by M. Teisserenc de Bort at his observatory at Trappes, by very frequent investigations, notably from January 27 to March 1, 1901, have proved that continuity is the most important matter and worthy of every effort. This is the reason why, in consequence of a report addressed by Teisserenc de Bort to M. Mascart, Director of the French Meteorological Service, the latter invited the meteorological institutions of Sweden and Denmark to unite in a scientific enterprise, in order to make meteorological investigations of this kind.

The delegates of the three countries, Messrs. Teisserenc de Bort, Hildebrandsson, and Paulsen met in the month of May, 1902, and chose as the seat of this experiment an extensive moor situated about 10 kilometers from the City of Viborg, in Jutland (latitude, 56.5° north; longitude, 9.2° east). This is a region where barometric depressions are of very frequent occurrence, and where the orography lends itself admirably to the maneuvers necessary in sending up kites. The proprietor, Mr. Krabbe, master of the hounds to the Court of Denmark, kindly offered to the expedition the use of the ground and his own personal assistance in the erection of the buildings and the making of contracts with the merchants and manufacturers of that region. Thanks to his zeal and devotion, the buildings were put up very rapidly. The preliminary investigations began in the month of June, and since the month of August the meteorological work has been carried on almost continuously. As this is the first undertaking of the kind, some details of the organization of the work may be of interest.

As already stated, the station is some distance from Viborg, which is, however, the nearest railway station. For investigations of this kind it is, of course, necessary to get away from railroads in order to avoid accidents and difficulties. It was also desirable to avoid being too near to the ocean, as that would entail the loss of a great number of instruments and kites.

The meteorological center of the station is an elevated tower on a hill, 11 meters in height, about 200 meters from the other buildings. This tower was constructed at Stockholm, according to the design of M. Teisserenc de Bort, and transported to Viborg. It is 10 meters in height and open on one side; it turns upon two circular rails so that it can face in any direction. Care is taken to turn the open side away from the wind. The building is of two stories; on the ground floor is the apparatus necessary for the kite service. On one side a small cottage has been provided for the meteorologist on duty. There he has under his eyes a self-registering barometer, and the recording apparatus of an anemometer which is on the roof of the tower. At the farthest side of the large room a table and tools for the construction and repair of the kites are placed, so that the workmen may be employed on such work when they are not necessary at the windlass. In the front portion of this room there are two windlasses, each furnished with a line of steel wire, composed of wires increasing in size from 0.6 millimeter to 1.3 millimeters in diameter, according to the system invented by Teisserenc de Bort, and which has been in use for a long time at the Trappes Observatory. At the top of the line there is a buckle which is attached to the first kite. About 150 meters below it the instrument for recording the meteorological elements is attached. The attachment is made either by means of a clamp or by a ligature. The ligatures serve to fasten together two ends of wire, either of the same or of different dimensions; they are made as follows: The two ends of the wire are twisted in the form of a spiral, and these spirals are entwined one inside of the other. There is on the average about one ligature for every 500 meters of wire, and if need be other kites are hooked on when the angle of the line becomes too weak. The two windlasses are worked by a small electric dynamo which receives its current from a generator placed in a small building alongside of the other houses and driven by a steam engine of 12 horsepower.

The first story of the tower serves as a storehouse for the kites. There are quite a number there of different dimensions, calculated for use in winds of greater or less force, and all ready to be hooked on to the line.

The other buildings consist of a balloon shed, a workshop for the construction of kites and self-registering instruments, and some sleeping rooms for a part of the personnel, kitchen, offices, a large room for testing the instruments, etc., stables and carriage houses, a small house for the steam engine with a bedroom for the mechanicians. Finally, the director of the station, M. Teisserenc de Bort, occupies a small cottage which he has built near the workshops.

As the principal object of the expedition is continuity in the observations, the service has to be carried on day and night, and this requires quite a numerous personnel. The three countries are represented by scientific assistants, two French, two Swedes, and one Dane, a lieutenant-colonel in the Danish army. There are besides a computer and a noncommissioned officer of the Swedish navy, attached to the station by the Minister of the Navy. For the construction of the instruments there are two French mechanicians from the observatory of dynamic meteorology and two Danish clock makers. Eight workmen are employed at the windlasses, a French cabinet maker, and a foreman who directs the work of construction and repairs, a chief constructor of kites, assisted by from four to six carpenters is charged with providing for the needs of this service; two mechanicans keep the motor in working order. To these there must also be added a coachman, a seamstress to sew the kites and two women cooks.

The principal work is the sending up of the kites. Every day when there is sufficient wind—and the wind does not often fail at this place—an ascension must be made. The scientific assistants relieve each other at the windlass as chiefs of service, each one being on duty from eight to nine hours; in the same way the workmen are organized into sets of twos. An ascension begins as soon as the wind allows of it. The self-registering instrument records the barometric pressure, the temperature, the humidity, and the force of the wind. The observations at the surface of the ground are made every half hour. The ascension continues until the cable is all played out or until the descent is rendered necessary either by a rupture of the wire or for any other reason. The dynamo is then set in motion, which is a signal for the mechanician to start the steam engine, which is kept under pressure day and night, and the cable begins to wind itself up. If the instrument is successfully brought down without damage, another one, already prepared for that purpose, is immediately hooked on, and a new ascension is begun without its being necessary to bring down the top kite. As soon as the instrument descends, the work of comparison, the abstract of the curves, and the tabulation of the results are begun in the bureaus. In the case of a breakage, it is necessary to wait until the instrument is brought back, which requires generally two or three days. For this purpose a letter attached to the basket containing the instrument tells the finder where to send it, and offers him a reward of 7 francs. It happens sometimes, however, that strong winds carry a line of several kilometers in length, with half a dozen kites and the self-registering instrument away to very great distances. In this connection, it may be interesting to cite two cases in particular where the kites crossed the sea.

In the first instance a west-northwest wind broke the line, and after remaining several days without any tidings of the instrument, the conviction gained that it had fallen into the sea in the direction of Aarhuus, in Jutland, and it was given up for lost. Sometime later a letter was received, which announced that a self-registering instrument had been found to the north of the island of Seeland (or Zealand). At first it was supposed that it was an instrument from a sounding balloon, but when it was received it was found to be one which had broken away with the line about twelve days before. Consequently, the kites, after having fallen into the sea on the east coast of Jutland, had crossed the Cattegat, and gone about 150 kilometers from their starting point.

The second instance is still more curious. After a breakage, in a southwest wind, and several weeks having elapsed without any tidings of the lost line, a dispatch was received from Christiansund in southern Norway, announcing that a kite of a certain number had been found near the coast. On examining the diary of the ascension, it was ascertained that the said kite had been attached to the lost line, but below the self-register; the hope was therefore entertained that the upper kite and the apparatus had been carried still farther away and would still be found, and this also happened. The apparatus having been recovered, the different phases of this journey of more than 200 kilometers, over the plains of Jutland and the Skagerack, could be traced by means of the curves.

A consideration of all the ascensions shows that in these countries it is very easy to attain heights of 1500 to 2000 meters, as the wind is generally sufficiently strong in the lower strata. On the other hand, ascensions to great heights, 3000 to 4000 meters, are relatively rare, notwithstanding all the efforts that have been made to attain them. This would tend to prove that the mean velocity of the wind, which is very great near the ground, approaches more nearly to the ordinary rate in the higher strata. It may also be stated that the difficulties and the cost of materials increase enormously when it is intended to make ascensions in all kinds of weather. In fact, it very often happens that in rather strong winds the tension on the line increases in proportion as the wire is unwound, while the angle of inclination of the wire constantly diminishes. In order to ascend higher we are forced to add another kite, and although care is taken in such cases to provide them with a copper wire "casse" which breaks when the pressure of the wind becomes too great, yet we see the total tension steadily increasing and finally attaining the breaking limit without the kites being detached. In spite of all possible precautions, ruptures are still numerous, and it has happened that more than 14,000 meters of the steel wire, 15 kites, and 3 instruments (which, however, were afterwards recovered) have been lost in less than twenty-four hours. It may, therefore, easily be imagined that under these circumstances the service of continuous ascensions becomes very difficult.

In addition to the kite ascensions, sounding balloons for the exploration of the middle strata of the atmosphere are also sent up. As it has been impossible to obtain hydrogen gas on reasonable terms, the balloons have had to be filled with illuminating gas. This has been found sufficient, as there was no intention of sending them up to great heights. The small area of the country makes it necessary to restrict the duration of the ascensions to twenty minutes or half an hour if one does not wish to run the risk of the balloons falling into the sea, and this is the reason why the balloons attain only relatively low altitudes (5 to 8 kilometers). The gas, manufactured at the gas works of Viborg, is brought in a large reservoir balloon made of cloth and sufficiently heavy to counteract its ascending power. It is brought on a wagon constructed for that purpose, and the gas is passed into balloons made of "papile," sent from the Trappes Observatory and which hold about thirty cubic meters. On an average one balloon is sent up every two days, and in special cases one every day. A clock movement tears them open after a certain interval of time, and a letter promises 14 francs[1] to the person who finds the instrument and returns it. Nearly all the instruments have been recovered, and the curves thus obtained complete the data obtained simultaneously by the kite ascensions. In a great number of cases at Trappes sounding balloons have been sent up the same day, and this gives very interesting points of comparison.

Finally, in cases where there has been no wind for a certain length of time a balloon kite has been used, although very rarely. The illuminating gas does not, however, suffice to make it rise, and it has served especially as a kite having no weight; it has, however, been quite interesting from a technical point of view to confirm the utility of such an apparatus. However, on account of the great difficulties attending the preparation and the maneuvers of this apparatus, we have not been able to study it very thoroughly, and the prevalence of strong winds has rendered its use unnecessary.

The experience gained during nine months of work at this station has led to interesting conclusions from a theoretical as well as from a technical point of view. The tables of the results obtained have been printed promptly in instalments and will be published, it is hoped, a few weeks after the observations have ceased. It has been demonstrated that there would be a great advantage in being able to modify the force of the wind artificially when it is insufficient, but especially when it is too strong. This is the reason why a small maritime expedition in Danish waters is being prepared, which is to conclude this work. The Danish navy has placed a gunboat at the service of the expedition for about three weeks.

On the whole, it may be considered that the work done at the Franco-Scandinavian station is a great step toward the end in view: continuity in observations of this kind. There were some periods of an absolute continuity of seventy-two hours, and several times it was possible to study the different phases of the barometric depressions which passed over that region.

## NOTE ON THE RADIATION FORMULAS AND ON THE PRINCIPLES OF THERMOMETRY.

By Edgar Buckingham, Bureau of Soils, United States Department of Agriculture.

On page 561 of the Monthly Weather Review for December, 1902, there are certain statements which, it seems to the writer, should not be allowed to pass without comment. In the second column (lines 23–29) it is stated that "Since $J_o$ is the integral of the area of the curve of energy intensity, it should evidently be greater than $J_m$ under all circumstances, but the fact that by this formula (IV) it becomes less for temperatures above 4119° seems to indicate that there may be something wrong in the deduction of formula III for $J_m$ and II for $J_o$, from which IV for $\frac{J_m}{J_o}$ was derived."[2] This sentence suggests several remarks.

[1] About $2.80.

[2] The equations in question are,

$$\text{II. } J_o = \text{const} \times T^4; \quad \text{III. } J_m = \frac{c_1}{c_2} \frac{5^5}{10^{5M}} T^5; \quad \text{IV. } \frac{J_m}{J_o} = \text{const} \times T.$$